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ABSTRACT

The purpose of this study was to determine whether high school seniors (N=492) had attained each of five selected earth science concepts and if said attainment was influenced by the number of science courses completed. A 72-item, multiple-choice format test (12 items for each concept) was developed and piloted previous to this study to measure these concepts: (1) cause of the seasons; (2) interdependence of man and environment; (3) changing earth; (4) day and night; and (5) solar energy. Concept attainment was arbitrarily set at 80%, which translates to 9.6 questions being answered correctly for each set of 12 items per concept. Significant differences in concept formation were observed across the sample and found to be influenced by the quantity of science courses the seniors had completed. While expected, these results lend credence to the notion that secondary science curricula stress concepts and their application. (Author/JN)

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Attainment of Selected Earth Science Concepts By High School Seniors

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> Anyone who pauses long enough to give the problem some serious thought cannot escape the conclusion that man lives in a world of concepts rather than a world of objects, events, and situations.
>
> Ausubel, 1968

Two decades ago, the National Science Teachers Association (NSTA) devoted five years to examining its beliefs and goals about the science curriculum (NSTA, 1964). At that time at the conference on Science Concepts, the NSTA Curriculum Committee (1964) reported a need for developing a framework of science concepts for a K-12 science curriculum. Since then, . science education projects and textbooks have focused on concepts and concept processes (Brandwein, P. F., Brovey, D. J., Greenstone, A. W., & Yasso, W. E., 1975).

Claiming that every citizen needed to be scientifically literate, the NSTA (1971) again emphasized a need for the knowledge of basic science concepts. Pella (1975), the National Assessment of Education (1975), and Showalter (1975) have subsequently reinforced knowledge and application of basic science concepts as characteristics of scientific literacy.

In 1969, the National Assessment of Educational Progress (NAEP) became the first project to assess and compare the science attainment of three schoolage youngsters, i.e., 9, 13, and 17 (NAEP, 1975). In the ensuing decade, the NAEP conducted three national assessments and reported how students classified by age, sex, race, region of the country, level of parents' education, and community size and type, responded to biological and physical

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science exercises.

The latest NAEP (1978) results has revealed a continued decline from earlier assessments of science attainment among seventeen year old learners while scores from younger learners (ages 9 and 13) appear to have leveled-off from declining trends exhibited previously. Given these findings, a panel was formed to examine the results and implications of the assessment in the light of current trends in science education (NAEP, 1978). This panel has suggested that the attainment of the 17-year-old may have declined, in part, because high school science courses are often elective after the tenth grade. The panel also suggests that the present science curriculum, which stresses concepts as well as problem-solving and decision-making, is quite different from the fact-oriented items reflected in the NAEP assessment. These comments raised concern from many quarters regarding the methods NAEP used for determining science attainment. Commenting on the implications of the NAEP, Tyler (1977) urged school officials to conduct assessments similar to the national assessments in their own schools. Further, he encouraged officials to relate their local findings to the national findings.

Unfortunately only isolated questions within the NAEP science tests address earth science topics. Further, while investigations examining the levels of concept acquisition by young learners (elementary and secondary levels) of physical science, biology, and mathematics are reported (Canter & Herron, 1978; Kempka & Hodgson, Renner & Grant, 1978; Carroll, 1977; Clamann, 1976; Cramer, 1974); no reports of research of this nature have been located dealing with concepts from earth science. Thus, the purpose of this investigation has been to act on Tyler's (1977) aforementioned recommendation by conducting an assessment of the attainment of selected earth science conepts among grade 12 learners in one state. The following primary research question has been posed to guide this inquiry:

1. To what degree have high school seniors attained each of five selected earth science concepts.

If differences do exist among levels of concept attainment, than an attempt will be make to specify the extent formal coursework in science has influenced these differences. Accordingly, the secondary research question takes the form.

2. Is attainment of selected earth science concepts by high school seniors influenced by the number of science courses completed?

Method

Sample: Learners participating in this inquiry were twelfth grade students enrolled in 100 public high schools in Texas. Stratified random sampling was used to select high schools with different total enrollments from each of the twenty service regions of the Texas Education Agency. This procedure provided a geographically equivalent sample of schools across the state.

Subsequent to the selection of the participating schools, five senior students were randomly selected from each school. This procedure resulted in 500 learners being selected. However, due to incomplete and conflicting biographic information, data from eight Learners in this sample were deleted leaving a data file comprised of information from 492 learners. Participating students were asked to indicate coursework in science they had successfully completed or were taking on that date the test was administered. Table 1 provides a summary of their responses. It is important to note that the state requires a minimum of two years of science to fulfill the science requirements for high school graduation. Nearly half of the subjects in this investigation, 244, had completed the required science courses while 248 seniors had elected to take additional science courses.

place table 1 here

Instrumentation: An assessment instrument for earth science concepts was needed to provide the dependent variables for the research questions in this investigation. In the spring of 1978, instruments were not available which addressed the concepts considered to be universally addressed in Texas public schools. Thus, the following tasks were established to guide the development of an earth science concept test.

A) Earth science concepts are to be selected and justified.

B) A comprehensive analysis for each concept must be completed.

C) Test items are to be constructed which are consistent with a model for concept attainment.

D) A pilot study involving the test must be conducted.

E) Readability, reliability and validity of the test must be determined.

The following paragraphs describe procedures undertaken to address these tasks

Concept Selection: In the past a number of efforts have been directed at identifying earth science concepts suitable for elementary and secondary school learners (Caldwell, 1955; Henson, 1969; Janke, 1969; Janke & Pella, 1972; Gibbons, 1976). However, the concepts list developed by Janke (1969) was used as the basis for identifying the concepts addressed in this investigation. This decision was based on our familarity with this list and the observation that these concepts had been rank ordered in terms of their relative importance.

Concept Analysis: Six concepts were selected from this list for analysis given the scheme developed by Frayer, Fredrick, and Klausmeir (1969). However after pilot testing of the instrument, one concept was deleted, leaving the five concepts presented in table 2. The initial task in this analysis was to list several examples of the concept under review. Determining what the examples had in common served to aid in the identification of concept attributes.

The second task in analyzing a concept was to identify the relevant

and irrelevant attributes or properties of the concept. Relevant attributes are properties which are present in all examples of the concept while those properties that are characteristic of some, but not all, instances of the concept are irrelevant attributes.

Following the identification of the concept attributes, a hierarchy of the concept was identified. Supraordinate, coordinate, and subordinate concepts were named. In this system, a supraordinate concept is a more general and inclusive concept than the concept being analyzed. The supraordinate has some, but not all, of the relevant attributes of the concept. The coordinate concept, however, is on equal standing with the analyzed concept in that both are examples of the supraordinate concept but differ from one another in relevant attributes. Conversely, a subordinate concept is a division, or part, of the concept under analysis. Subordinate concepts possess all the relevant attributes of the concept as well as additional irrelevant attributes.

Next, the criterial attributes were isolated. Criterial attributes are those which distinguish the properties of the concept under analysis from its supraordinate or coordinate concepts. A definition was then formulated which included the name of the supraordinate concept and the criterial attributes. If the concept did not have a supraordinate concept, then the definition had to contain all the criterial attributes. Next, several examples and non-examples of the concept were identified.

The final step of the concept analysis scheme was to indicate how the concept was related to other concepts. This relationship was expressed as a principle. Care was taken not to use relationships involving criterial attributes, or relationships between concept examples. Results of these

analyses are presented in table 2.

place table 2 about here

Test Construction: The analyses of the earth science concepts provided the framework for constructing a pilot instrument to assess attainment of the selected concepts. A 12-item test was written for each of the selected concepts. A 12-term test was written for each of the concepts based on the following 12 prototype tasks developed by Frayer, et al. (1969) for measuring concept attainment:

1. Given the name of an attribute, select an example of the attribute.
2. Given an example of an attribute, select the name of the attribute.
3. Given the name of a concept, select the example of the concept.
4. Given the name of a concept, select the non-example of the concept.
5. Given an example of the concept, select the name of the concept.
6. Given the name of the concept, select the relevant attribute.
7. Given the name of a concept, select the irrelevant attribute.
8. Given the meaning of a concept, select the name of the concept.
9. Given the name of a concept, select the meaning of the concept.
10. Given the name of a concept, select the supraordinate concept.
11. Given the name of a concept, select the subordinate concept.
12. Given two concepts, select the principle relating them.

Using a multiple choice format with four alternative answers, a 72-item pilot instrument was constructed.

The resulting instrument was reviewed by a panel to determine whether the item sets for each concept accomplished the forementioned tasks. An earth science education specialist, two science educators, a professor of geology, and a psychometrician comprised the panel. Subsequent to this review a number

of item modifications were made, then the items were randomly assigned to positions in the test instrument.

Pilot Test: A pilot administration of the test was conducted during the spring of 1978 with 180 secondary learners. Findings from this administration included a reliability estimate (K-R-20) of .89, and the observation that the 72 item test required more than the 45 minute time limit we felt was necessary to fit established schedules within most high school situations. Thus a concept which was attained by 80 percent of the learners in the pilot sample was omitted from the final instrument leaving some 60 items which were associated with five concepts.

Readability, Reliability and Validity Checks: The readability of the final draft of the instrument was determined to be on the 6.3 grade level using the Fry Readability Scale (Fry, 1968). In addition a reliability determination was again made since the final version of the instrument contained fewer items than the original version. The K-R-20 value for the final version was determined to be .894. As a final check, the revised instrument was submitted to a final validity check by a panel of science educators. This panel evaluated the items for content validity and assessed the version to be acceptable and ready for use.

Collection of Data

Each of the schools agreeing to participate in the study were assured in writing that neither school names nor student names would be used in any form in reporting the results of the inquiry. Administrators of participating schools provided a commitment card 3 months before the tests were administered indicating the school's intention to particate in the inquiry. In addition, the name of the individual designated to administer the test was provided as well as the number of students enrolled in the twelfth grade. Subsequently, on January 2, 1979 to be exact, a test packet containing the test instruments, answer sheets, demographic data sheets, learner selection procedures, test directions, and return mailer was mailed to each participating school. Directions in the packet requested the

individual responsible for administering the test to return the completed tests by January 31, 1979. Response was high with reminder calls being made to four schools who did not return the answer sheets by the specified date. All data were remitted to the investigators within two weeks of the remainder calls.

Results and Discussion

Attainment of a concept was arbitarily set at 80 percent, which translates to 9.6 questions being answered correctly for each set of 12 items/concept. While this criterion does not permit the performance of each learner to be examined with respect to concept attainment this is of little concern since we have chosen the concept as the unit of analysis. In other words, group performances are reported for each concept and for all concepts combined. Values addressed to research question one are presented in table 3.

place table 3 about here

Table 1 values indicate that the seniors in this investigation attained the environment concept, ($\overline{X}$=9.7) and nearly attained the changing earth concept, ($\overline{X}$=9.5) and the day and night concept ($\overline{X}$=9.5) given the criterion level we established (criterion score = 9.6). Clearly, these seniors as a group failed to achieve the seasons concept ($\overline{X}$ =8.0) and the solar energy concept ($\overline{X}$=7.1). Examining the data revealed that they were able to successfully distinguish examples from non-examples across the concepts examined in most instances but were unsuccessful in relating concepts together forming supraordinate concepts, and principles for the seasons and solar energy concept in particular.

Since differences in concept attainment were found to occur for the total sample, efforts were extended to determine whether these differences were associated with the numberof science courses completed by the subjects. Concept means between seniors who had completed the state required two years of high school

science and those who had elected to complete additional science coursework are presented in table 4. In reviewing these values it is important to note that

place table 4 about here

without exception, seniors who had completed additional science courses attained significantly higher scores on all five concepts and on the total score than did their counterparts who completed only the required science courses. Examining these group means from the perspective of criterion scores, we find that not one of the concepts was achieved at the 80 percent level of attainment by the learners who had completed only the state required science coursework. Conversely, seniors who had completed additional science coursework successfully attained three concepts, namely, environment, changing earth, and day and night. This finding corresponds with the findings cited by Cramer (1974) and by Renner and Grant (1978) who have reported similar results with concept attainment in mathematics and physics, respectively.

In reviewing the values in tables 3 and 4 it is important to note the required science courses most often reported include physical science, general science and biology; while the elective courses include chemistry, physics, advanced biology, and advanced chemistry. It is quite possible, the concepts addressed in this investigation were not formally treated in the high school science coursework completed by the subjects. If this is phenomenon is indeed the case, why have these differences occurred? Was it because of content integration throughout the secondary science curriculum to the degree that these earth science concepts were repeated and integrated in biology, chemistry and physics in a formal sense. This is a potential explanation, especially if the seniors were from one school with a problem-centered curriculum. However this explanation does seem improbable because learners from 100 different

schools distributed across the state of Texas participated in this inquiry. Further, secondary level curriculum documents are notoriously content-centered, not problem centered, thus the notion of an integrated science curriculum for high school sciences is certainly not the norm.

An alternate explanation for these findings is that concept tranfer has occurred in the additional science coursework through informal processes. Perhaps these concepts have not been directly addressed, yet it is feasible that numerous instances have occurred where the environment, changing earth, and diurnal period have been used as examples and non-examples in biological and physical science instructional strategies. Under these circumstances, the learner would be reminded of the concepts and possibly would attain additional attributes of the concept. If additional attributes of the concept were attained the learner possibly would be more adept at using the concept for more than a label, that is, he would be able to cite subordinate and supraordinate concepts associated with the concept class and relate the concept to other concepts as principles. Whether this latter explanation accurately describes how the seniors with additional science acquired their understanding of these earth science concepts is strictly conjecture. However, we have noted from the responses to the test items which required such understanding, that seniors with additional science have demonstrated these abilities, while their counterparts who have completed only the state required science coursework have not been successful with classification tasks involving these concepts.

Concluding Remarks

This investigation was conducted to determine whether high school seniors had attained selected earth science concept. Significant differences in concept

attainment were observed across the sample. These differences were found to be influenced by the quantity of science courses the seniors had completed. While expected, this result lends credence to the notion that secondary science curricula stresses concepts and their application.

A variety of sources were reviewed in identifying and delimiting the earth science concepts for this inquiry. Yet, the most influential source for this research endeavor addressed the concept analysis schema and prototype tasks for concept attainment. These parameters were developed by Frayer, Fredrick and Klausmeir (1969). Given these schema and procedures, the task of constructing a set of test items to measure attainment of a concept was challenging yet rewarding since the resulting set of items provided the basis for addressing the level of attainment of the concept. However, we have not addressed the level of attainment issue in this investigation. Rather, we have defined concept attainment in an arbitrary manner, that is, 80 percent of the items answered correctly. The reason for choosing the less demanding concept attainment task as defined here rather than the level of concept attainment task centers on the number of correct performances at each level to demonstrate mastery. Is one correct response sufficient or must we have multiple correct responses for each level of attainment? Since we have assumed the conservative stance, of multiple responses per level, then twelve items per concept would simply not suffice. Thus, we were left with the dilemma of testing two concepts for level of attainment or multiple concepts simply for attainment. While we chose the multiple concept option, the issue of levels of concept attainment is intriguing and holds much promise for meaningful research on concept attainment in all areas of science instruction.

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TABLE I

NUMBER AND PERCENT OF STUDENTS WITH SCIENCE COURSES
IN ADDITION TO THE STATE REQUIREMENTS

NUMBER OF ADDITIONAL COURSES	NUMBER OF STUDENTS	PERCENT
1 (a)	144	29.3
2 (a + b)	79	16.0
3 (a + b + c)	21	4.3
4 (a + b + c + d)	4	0.8
TOTAL STUDENTS WITH EXCESS COURSES	248	50.4
STUDENTS WITH STATE REQUIRED COURSES ONLY	244	49.6
TOTALS	492	100.0

a - CHEMISTRY b - PHYSICS c - BIOLOGY II d - OTHER SCIENCE COURSES

TABLE II

ANALYSES OF FIVE EARTH SCIENCE CONCEPTS INCLUDED IN THE TEST OF CONCEPT ATTAINMENT

Analysis Component	CONCEPTS 1	2	3	4	5
CONCEPT LABEL	Cause of the seasons	Interdependence of man and environment	Changing earth	Day and night	Solar energy
DEFINITION	The seasons are a result of the revolution of the earth about the sun and the tilt of the earth's axis	Man and the environment are influenced by each other	The earth formed billions of years ago and has been undergoing change since its formation	The earth rotates around its axis, and this rotation produces day and night	The sun directly or indirectly supplies almost all the energy available on the surface of the earth
SUPRAORDINATE CONCEPT	The earth's motions	Conservation	Uniformitarianism	Planetary motion	Electromagnetic radiation
COORDINATE CONCEPT	Cycles of climate	Biosphere	Changing oceans	Revolution of the earth	Earth's internal energy
SUBORDINATE CONCEPTS	Tilt of the earth's axis; revolution of the earth around the sun	Living systems; non-living systems	Deposition; erosion	Length of day; length of night	Ultraviolet; infrared
CRITERIAL ATTRIBUTES	Seasons begin or end on equinox or solstice	Conservation of energy; conservation of matter	Earth's surface wearing away and building up	Periods of light and dark	Controls surface temperature of the earth
RELEVANT ATTRIBUTE	Occur periodically	Natural resources	Energy transfer	Rotation of the earth	Radiation
IRRELEVANT ATTRIBUTE	Hurricanes	Self-healing environment	Gravity	Different lengths of day	Visible light
PRINCIPLE OR RELATIONSHIP BETWEEN TWO CONCEPTS	The seasons and the climate are controlled by the sun	Man can use solar energy to extend resources in his environment	Both the earth and the environment are changing	The seasons and day and night are caused by the motion of the earth	Solar energy can be used to conserve fossil fuel
CONCEPT EXAMPLES	Spring, summer, autumn, winter	Water; energy; pyramids	Mountain forming, valley erosion, earthquakes	Morning, noon, evening, midnight	Direct: heat and light Indirect: coal and wood
CONCEPT NON-EXAMPLES	Indian summer; direction the earth turns	Gravity; inertia	Moonquakes; magnetism; northern lights	The revolution of the sun; inertia	Geo-thermal heat; volcanoes; earthquakes; nuclear energy

TABLE III

STUDENT CONCEPT MEAN SCORES AND CONFIDENCE LEVELS
USED TO DETERMINE CONCEPT ATTAINMENT (n = 492)

CONCEPTS	MEANS	STANDARD ERROR OF MEANS	CONFIDENCE LEVELS*	CONCEPT ATTAINMENT AT 80% LEVEL
SEASONS	8.0	0.106	7.8 - 8.2	NOT ATTAINED
ENVIRONMENT	9.7	0.106	9.5 - 9.9	ATTAINED
CHANGING EARTH	9.5	0.099	9.3 - 9.7	NOT ATTAINED
DAY AND NIGHT	9.5	0.097	9.2 - 9.7	NOT ATTAINED
SOLAR ENERGY	7.1	0.105	6.9 - 7.3	NOT ATTAINED
ALL CONCEPTS	43.8	0.412	43.0 - 44.6	

* USED 1.96 TO DETERMINE CONFIDENCE LEVEL AT 95% RANGE

TABLE IV

DESCRIPTIVE STATISTICS AND TEST OF SIGNIFICANCE FOR CONCEPT ATTAINMENT BASED ON SCIENCE BACKGROUND OF LEARNERS

CONCEPTS*		SCIENCE BACKGROUND		TEST OF SIGNIFICENCE	
		STATE REQUIRED n = 204	ADDITIONAL SCIENCE n = 248	t	P
SEASONS	MEANS	7.3	8.4	5.42	<.001
	S.D.	2.3	2.2		
ENVIRONMENT	MEANS	9.1	10.1	4.95	<.001
	S.D.	2.6	1.8		
CHANGING EARTH	MEANS	8.9	10.1	6.28	<.001
	S.D.	2.4	1.8		
DAY AND NIGHT	MEANS	9.0	10.0	5.39	<.001
	S.D.	2.2	1.9		
SOLAR ENERGY	MEANS	6.4	7.9	7.73	<.001
	S.D.	2.1	2.2		
ALL CONCEPTS	MEANS	40.6	46.7	8.01	<.001
	S.D.	9.0	7.8		

*12 QUESTIONS PER CONCEPT